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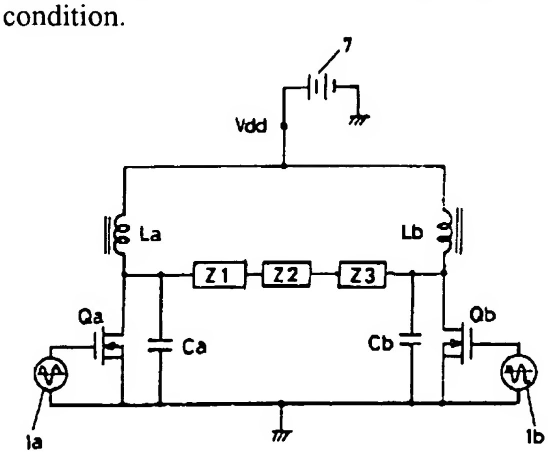
(54) **[Title of the invention]** Class E push-pull power amplifier circuit

(57) **[Summary]**
[Objective] To provide a circuit composition wherein two switching elements are easily operated under ideal condition or near that condition, in class E push-pull power amplifier circuit

[Constitution] In call E push-pull power amplifier circuit wherein a parallel circuit of switching elements Qa and Qb and capacitors Ca and Cb is connected to a DC power supply 7 through inductors La and Lb, a resonance circuit is connected between connecting points of the inductors La and Lb, and a load circuit is connected to the composing elements of the resonance circuit in parallel; said resonance circuit comprises three elements of the first, second and third elements in this order of being connected in series, and the first and the third elements at the both ends have nearly equal impedances.

[Effect] It enables to make copper foil pattern of print circuit board symmetrical at fabrication of the circuit making it easy to operate under ideal condition or near that condition.



[Claims]

[Claim 1] In a class E push-pull power amplifier circuit comprising the first and the second inductor wherein on end of each of them is connected to one side of terminals of a DC power supply, the first and the second switching element being connected between the other terminal of the DC power supply and the other end of the first and the second inductors respectively, drive means which alternatively turn on and off the first and the second switching elements, the first and the second capacitors which are connected in parallel with each of the first and the second switching elements, a resonance circuit which is connected between each of said the other ends of the first and second inductors, and a load circuit being connected in parallel with one of the elements comprising said resonance circuit; class E push-pull power amplifier circuit which is characterized that said resonance circuit comprises the first, the second and the third elements in the order of being connected in series, and the first and the third element at both ends have nearly equal impedance.

[Claim 2] Class E push-pull power amplifier circuit which is described in Claim 1 and characterized that the first element of said resonance circuit is capacitive element, the second element of it is inductive element, and the third element of it is capacitive element.

[Claim 3] Class E push-pull power amplifier circuit which is described in Claim 1 and characterized that the first element of said resonance circuit is inductive element, the second element of it is capacitive element, and the third element of it is inductive element.

[Claim 4] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 3 and characterized that a load circuit is connected in parallel to the second element among the first, second and third elements of said resonance circuit.

[Claim 5] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 3 and characterized that a load circuit is connected in parallel to the first and the third elements among the first, second and third elements of said resonance circuit.

[Claim 6] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 5 and characterized that the second element at the center among said three elements of the resonance circuit is substituted with the fourth and fifth two elements being connected in series so that the impedance is nearly equal to the second element, and the connecting points between the fourth and the fifth elements is connected to said other side of terminal of the DC power supply.

[Claim 7] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 6 and characterized that said first and second switching elements are elements having output capacitance and the output capacitance is used as entire or a part of the first and second capacitors, respectively.

[Claim 8] Class E push-pull power amplifier circuit which is described in one of Claim 7 and characterized that said elements having output capacitance are field effect transistors.

[Claim 9] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 8 and characterized that said load circuit is connected through a transformer and said leakage inductance is used as a inductive component of said resonance circuit.

[Claim 10] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 9 and characterized that said load circuit is connected through a transformer, said transformer is a nearly ideal transformer having leakage inductance being nearly zero and mutual inductance is nearly infinitive, and a coreless coil is connected with the secondary coil of said transformer in parallel with the load circuit.

[Claim 11] Class E push-pull power amplifier circuit which is described in one of Claim 1

through 10 and characterized that said load circuit is composed with an electrode-less discharging lamp, an inductive coil being wound near the electrode-less discharging lamp, and a matching circuit for efficiently supply power by matching the impedance.

[Claim 12] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 11 and characterized that it is constituted that it is mounted on a print circuit board and impedance by copper foil pattern is made to be uniform against the first and second switching elements.

[Claim 13] Class E push-pull power amplifier circuit which is described in one of Claim 1 through 12 and characterized that the first and the second inductors show nearly equal inductive impedance and the first and the second capacitors show nearly equal capacitive impedance.

[Detailed explanation of the invention]

[0001]

[Application field in industry] This invention concerns class E push-pull power amplifier circuit, and it is used as high efficiency high frequency power amplifier for lighting device for electrodeless discharge lamps, for example.

[0002]

[Prior technology] Previous class E single ended power amplifier circuit is shown in Figure 15. In the Figure, 1 shows high frequency wave oscillator, 2 shows class E power amplifier circuit and 3 shows load. The class E power amplifier circuit 2 comprises a switching element Qa which is connected to a DC power supply 7 in series, an inductor La which is to control input current from the DC power supply 7 to be nearly constant, a capacitor Ca which is connected to the switching element Qa in parallel, and a series circuit of resonance coil L and a resonance capacitor C which has a resonance point near the operational frequency. Where, the capacitor Ca being connected to the switching element Qa in parallel may be substituted with or partially shared with the output capacitance of the switching element Qa.

[0003] Wave shapes of voltage Va at both terminals of the switching element Qa and current Ia running through the switching element Qa are shown in Figure 16. The characteristic of the class E operation is that switching loss is nearly zero when the switching element transits from ON to OFF because Ia starts to run immediately when value and slope of the voltage Va turns to be zero. Accordingly highly efficient power amplification is realized even at high frequency by using a class E power amplification circuit.

[0004] When output of the class E single ended power amplifier circuit is increased, the loss at the switching element Qa also increases along with the increase of output, and temperature of the switching element Qa rises with generated heat. Due to this temperature increase of the switching element Qa, there are cases that increase of output is restricted with the single ended power amplifier circuit of Figure 15.

[0005] Accordingly, class E push-pull power amplifier circuit has been invented as shown in Figure 17, using two switching elements Qa and Qb, based on the class E single ended power amplifier circuit of Figure 15. In this circuit, a circuit wherein an inductor La is connected in series with a parallel circuit of a switching element Qa and a capacitor Ca, and a circuit wherein inductor Lb is connected in series with a parallel circuit of a switching element Qb and a capacitor Cb, are connected to a DC power supply 7 in parallel. One end of each of the inductors La and Lb is connected to one side of electrodes of the DC power supply 7, and a series circuit of resonance coil L and resonance capacitor C having a resonance point near the operational frequency is connected between the other ends of the inductors La and Lb. Leakage inductance of the output transformer T is used

as the resonance coil L. A load R is connected to the secondary coil of the output transformer T. The switching elements Qa and Qb are alternatively turned on and off, and their drive signal sources 1a and 1b are obtained by converting output of the high frequency oscillator 1 of Figure 15 into two signals in opposite phase with a transformer having a center tap as shown in Figure 18, for example. Higher output of class E power amplifier circuit is enabled by making it as a class E push-pull power amplifier circuit as shown in Figure 17, because it is able to share the loss at the switching element with two switching elements Qa and Qb and suppress the temperature increase accompanied with the loss at each of the switching elements Qa and Qb.

[0006] Operating wave shape of the class E push-pull power amplifier circuit of Figure 17 in ideal condition is shown in Figure 19. As shown in Figure 19, it is able to make the switching loss nearly zero when the switching elements Qa and Qb transit from OFF to ON and highly efficient power amplification is realized because electric currents Ia and Ib start to run through each of the switching elements Qa and Qb at the same time when voltages Va and Vb being applied to each of the switching elements Qa and Qb are zero and slope of the voltages Va and Vb turn zero.

[0007]

[Problems to be solved by this invention] In designing power amplifier circuit using a resonance system such as class E push-pull power amplifier circuit, it is important to have it operate at an ideal condition as shown in Figure 19 or close to that condition, in order to realize high efficiency power amplification. However in high frequency circuit, copper foil pattern of print circuit board functions as inductance or capacitance. Because of this, there are cases that mismatching in operation conditions may occur between two switching elements Qa and Qb as shown in Figure 20 due to such as impedance of copper foil when the class E push-pull power amplifier circuit of Figure 17 in actually mounted. Accordingly, an situation frequently occurs that adjustment for operating two switching elements Qa and Qb simultaneously at an ideal condition as shown in Figure 19 is difficult. Because of this, there are many cases that obtaining the power amplification efficiency which is possessed by a class E push-pull power amplifier circuit in ideal condition as shown in Figure 19 is difficult.

[0008] This invention was conducted considering above described point, and its objective is to provide a circuit design which is easy to operate two switching elements at an ideal condition or a condition close to that, in class E push pull power amplifier circuit.

[0009]

[Means to solve the problems] With the class E push-pull power amplifier circuit of this invention, as shown in Figure 1, in order to solve above described problem; in a class E push-pull power amplifier circuit comprising the first and the second inductor La and Lb wherein on end of each of them is connected to one side of terminals of a DC power supply 7, the first and the second switching element Qa and Qb being connected to each of other terminal of the DC power supply 7 and the other end of each of the first and the second inductors La and Lb, respectively, drive means 1a and 1b which alternatively turn on and off the first and the second switching elements Qa and Qb, the first and the second capacitors Ca and Cb which are connected in parallel with each of the first and the second switching elements Qa and Qb, a resonance circuit which is connected between each of said the other ends of the first and second inductors La and Lb, and a load circuit being connected in parallel with one of the elements comprising said resonance circuit; it is characterized that said resonance circuit comprises the first, the second and the third elements Z1, Z2 and Z3 in an order of being

connected in series, and the first and the third elements Z1 and Z3 at the both ends have nearly equal impedance. Where, the second element Z2 is made to be inductive impedance when the first and the third elements Z1 and Z3 are capacitive impedance, and when the first and the third elements Z1 and Z3 are inductive impedance, the second element Z2 is made to be capacitive impedance. However, these capacitive elements and inductive elements may be acceptable if internal impedance of them have capacitive or inductive at near the operational frequency, and their internal constitution is not restricted.

[0010]

[Function] While a resonance circuit has been constituted with two elements of a capacitor C and an inductor L with previous class E single ended power amplifier circuit as shown in Figure 17, the class E push-pull power amplifier circuit of this invention is able to nearly symmetrically constitute and mount class E push-pull power amplifier circuit by constituting with the first, the second and the third elements Z1, Z2 and Z3 which are connected in series as shown in Figure 1, making impedances of the first and the third elements Z1 and Z3 on both ends be nearly equal, and making one side of the first and the third elements Z1 and Z3 or the second element Z2 be capacitive and the other be inductive; and is able to easily operate two switching elements Qa and Qb simultaneously at ideal condition as shown in Figure 19 or near the ideal condition.

[0011]

[Embodiment examples] Figure 2 is the circuit schematic of the first embodiment example of this invention. An explanation is made below on the constitution of the circuit. A pair of switching elements Qa and Qb are constituted with power MOSFET's and capacitors Ca and Cb are connected in parallel between their drain and source. Total of or a part of these capacitors Ca and Cb may be shared or substituted with output capacitance of the power MOSFET's. The source of each power MOSFET is grounded and connected to negative terminal of a DC power supply 7, and drain is connected to positive terminal of the DC power supply 7 through inductors La and Lb. Vdd indicates the voltage of the DC power supply 7. A resonance circuit being composed by connecting a capacitor C1, inductor L2 and capacitor C3 in this order in series is connected between the drain of each power MOSFET. Capacities of capacitors C1 and C2 on both sides are nearly equal, and a load R is connected to the inductor L2 in the middle. This resonance circuit has a resonance point near the operating frequency of the switching elements Qa and Qb. The switching element Qa and Qb to be alternatively turned on and off, and its drive signal source 1a and 1b are obtained by converting output of high frequency generator 1 of Figure 15 into two signals in opposite phases with a transformer having a center tap as shown in Figure 18, for example. Further, each of the inductors La and Lb shows nearly equal inductive impedance and each of the capacitors Ca and Cb also shows nearly equal capacitive impedance. According to this, entire circuit is composed to be symmetrical concerning the switching elements Qa and Qb. Further, the print circuit board on which this circuit is mounted is constituted so that copper foil pattern is nearly symmetrical and designed to have circuit constant at high frequency wave is symmetrical. This circuit has an advantage that number of parts is minimum among the constitutions which provide the effect of this invention.

[0012] Figure 3 is circuit schematic of the second embodiment example of this invention. In this embodiment example, primary coil of the output transformer T is connected to the inductor L2 in the first embodiment example being shown in Figure 2 and the load R is connected to the secondary coil of it. One end of the load R is connected to the ground of the circuit. In this embodiment

example, leakage inductance of the output transformer T is utilized as the inductor L2 and made to be the second element showing inductive impedance. Also, the capacitors C1 and C3 composes the first and the third elements which have nearly equal impedances. In this embodiment example, the high frequency output is taken out by using an output transformer T, therefore, one end of taken out high frequency output may be connected to the ground of the circuit which enables handling of the output easier with coaxial cable and connectors compared to the first embodiment example being shown in Figure 2.

[0013] Figure 4 is a circuit schematic of the third embodiment example of this invention. In this embodiment example, the primary coil of the output transformer in the second embodiment example is split into nearly equal and its center tap is connected to the ground of the circuit. When leakage inductances L2a and L2b of the primary coil being split into nearly equal are synthesized, it is equal to the inductor L2 of the second embodiment example which is shown in Figure 3. In comparison with the second embodiment example being shown in Figure 3, this embodiment example is able to reduce high frequency noise which is radiated from the circuit because the center point of the inductor L2 being split into two is connected to the ground of the circuit, and is able to stabilize terminal voltages of each element against high frequency wave as well, which has an effect of stabilizing the operation of entire circuit.

[0014] Figure 5 is a circuit schematic of the fourth embodiment example of this invention. In this embodiment example, a resonance circuit is composed by connecting primary coil of an output transformer T1, a capacitor C2 and primary coil of an output transformer T3 in the sequence in series. The secondary coils of the output transformers T1 and T3 are connected in series and connected to a load R. One end of the load R is connected to the ground of the circuit. Leakage inductance of the output transformers T1 and T3 are utilized as inductors L1 and L3 and made as the first and the second elements which show inductive impedance. Because high frequency output is able to be taken out by using two output transformers T1 and T3, there is an effect of simplifying heat loss design of the output transformers, and an effect of simplifying adjustment of the inductance value of the resonance circuit as well which is important for realizing high efficiency amplification in class E push-pull power amplifier circuit.

[0015] Figure 6 is a circuit schematic of the fifth embodiment example of this invention. In this embodiment example, the capacitor C2 in the middle as the second element in the embodiment example 4 being shown in Figure 5 is split into nearly equal two to compose a series circuit with two capacitors C2a and C2b and the connecting point of the capacitor C2a and C2b is connected to the ground of the circuit. When capacitors C2a and C2b which are split into nearly equal two are synthesized, it is equal to the capacitor C2 of the embodiment example 4 being shown in Figure 5. Compared with the fourth embodiment example which is shown in Figure 5, this embodiment example is able to reduce high frequency wave noise which is radiated from the circuit because the center point of the capacitor C2 being nearly equally split into 2 is connected to the ground, and is able to stabilize terminal voltages of each element against high frequency wave as well, which has an effect of stabilizing the operation of entire circuit.

[0016] Figure 7 is a circuit schematic of the sixth embodiment example of this invention. In this embodiment example, a resonance circuit being composed by connecting the inductor L1, capacitor C2 and inductor L3 in series in this order, is connected between drain of MOSFET's composing a pair of switching element Qa and Qb. On the both

ends of the center capacitor C2, primary coil of an output transformer T2 is connected. A load R is connected to the secondary coil of the output transformer T2. One end of the load R is connected to the ground of the circuit. Synthesized impedance of the leakage inductance of the output transformer T2 and the capacitor C2 composes the second element, and the circuit constant is set so that it is capacitive near the operational frequency. Because high frequency output is taken out through the capacitor C2 in this circuit, a low pass filter is composed with the inductor L1, capacitor C2 and inductor L3, and has an effect of reducing harmonic wave component which appears in the output. Further, there is an affect of preventing damage to the switching elements Qa and Qb by excess current even when the impedance which is viewed from the primary side of the circuit gets a condition of short circuit, because current runs through the resonance circuit is restricted due to the leakage inductance.

[0017] Figure 8 is a circuit schematic of the seventh embodiment example of this invention. In this embodiment example, the capacitor C2 as the center second element in the sixth embodiment example being shown in Figure 7 is split to nearly equal two to compose with a series circuit with two capacitors C2a and C2b, and the connecting point of the capacitor C2a and C2b is connected the ground of the circuit. When the capacitors being split to nearly equal two are synthesized, it is equal to the capacitor C2 of the embodiment example 6 being shown in Figure 7. Although inductance L2 exists in primary coil of the output transformer T2 due to leakage inductance, the circuit constant is set so that synthesized impedance of capacitors C2a and C2b is capacitive near the operating frequency. Compared to the sixth embodiment example being shown in Figure 7, high frequency component is connected through the capacitor C2 to the circuit ground because the center point of nearly equally split in two is connected the ground of the circuit in this embodiment example, therefore, the effect as said low pass filter is increased to increase suppression effect of harmonic wave and is able to reduce high frequency noise and able to stabilize terminal voltage of each element against high frequency wave which has an effect of stabilize the operation of entire circuit.

[0018] Figure 9 is a circuit schematic of the eighth embodiment example of this invention. In this embodiment example, a resonance circuit being composed by connecting a capacitor C1, an inductor L2 and a capacitor C3 in series in this order is connected between drains of MOSFET's which compose a pair of switching elements Qa and Qb. To the capacitors C1 and C2 at the both ends, primary coils of output transformers T1 and T3 are connected, respectively. The secondary coil of the output transformers T1 and T3 are connected in series and then connected to a load R. One end of the load R is connected to the ground of the circuit. The inductances L1 and L3 by leakage inductance of the output transformer T1 and T3 are connected with the capacitors C1 and C3 in parallel, and the circuit constant is set so that their synthesized impedance is capacitive near the operating frequency. In this circuit, it constitutes a low pass filter to output as same as the circuits of Figure 7 and Figure 8 to have an effect of reducing harmonic components of power which appear in output and to have an effect to prevent damage to the switching element, because high frequency output is taken from both ends of two capacitors C1 and C3. Also there is an affect to make design of heat loss and inductance value of output transformer easier as same as the circuits of Figure 5 and Figure 6, because the output transformer is split into two.

[0019] Figure 10 is a circuit schematic of the ninth embodiment example of this invention. In this embodiment example, the inductor L2 as the second element in the center in the

embodiment example 8 being shown in Figure 9 is split into nearly equal two to constitute with a series circuit of two inductors L2a and L2b, and the connecting point of the inductors L2a and L2b is connected to the ground of the circuit. In this case, a DC circuit is formed which connects from a DC power supply through the inductor La, inductor L1 and inductor L2a, or the inductor Lb, inductor L3 and inductor L2b to the ground of the circuit, therefore, in order to cut this DC circuit, capacitors C2a and C2b are connected to to two inductances L2a and L2b, respectively in series. Values of capacitors C2a and C2b are set to be nearly equal. Synthesized impedance of the inductors L2a and L2b being split into nearly equal two and capacitors C2a and C2b is set to be inductive near the operation frequency and to be equal to the inductor L2 in the embodiment example 8 being shown in Figure 9. Also, compared with the embodiment example 8 being shown in Figure 9, it is able to reduce high frequency noise being emitted from the circuit and able to stabilize terminal voltage of each element against high frequency wave because the center point of the inductor L2 which is split into nearly equal two, which has an effect of stabilizing operation of entire circuit.

[0020] Although the load R has been shown with a symbol of resistor, it may be such as a discharge lamp, for example. As an example of it, an embodiment example is shown in Figure 11 which uses an electrodeless discharge lamp which discharges and emits light with high frequency electromagnetic field as the load. In the Figure, 4 is an electrodeless discharge lamp, 5 is an induction coil being wound near the electrodeless discharge lamp 4, 6 is a matching circuit for matching impedances of the amplifier circuit and the discharge lamp 4 to effectively supply electric power. Where, constant of each circuit in each of above embodiment examples is of course adjusted to conduct class E operation.

[0021] By the way, in order to obtain ideal voltage wave profile and electric current wave profile as shown in Figure 19, design of resonance frequency is important in designing of a class E push-pull power amplifier circuit. Accordingly, fine adjustment of constant is required in may cases. As an example of it, there is a case of adjustment of the inductance of resonance coil. In the case of single ended circuit as Figure 17, a coreless coil is often used as the inductor L for high frequency and adjustment is relatively easy. However, with a class E push-pull circuit as Figure 12, because the inductor L2 for resonance is common with the output transformer T which is wound on iron core, therefore, adjustment of inductance is difficult. Further, inductance value has to be designed considering the leakage inductance at designing, and satisfying both function of transformer and the inductance value is very difficult. Accordingly, if the output transformer T is designed as an ideal transformer and the resonance inductor L2 is installed between said transformer T and resonance capacitor C1 or C3, the resonance inductor L2 may be made as coreless coil and fine adjustment becomes easy. However, if it is constituted as this Figure 13, being symmetrical is lost when actually mounting a class E push-pull power amplifier circuit. As described above, copper foil pattern of print circuit board may function as inductance with circuits handling high frequency wave, and asymmetrical in mounting is equivalent to being asymmetrical in constant of elements. Accordingly, it is ideal to constitute symmetrically from the drive circuit to the resonance circuit of output with a push-pull circuit as Figure 12. Therefore, installing resonance coils on both sides of said transformer is considered, however, it not only increases quantity of elements but also makes adjustment in good balance difficult. Accordingly, it is desirable to install a coreless coil L2 on the circuit on the secondary winding of the ideal transformer T2. With this, it is able to avoid the circuit constant

becoming asymmetrical by the copper foul pattern because it enables not to disturb the symmetrical constitution. Further, the adjustment of circuit operation may be easily done with said coreless coil L2. Further, designing of the output transformer T becomes easy because there is no need to provide leakage inductance to the output transformer T.

[0022]

[Effect of the invention] According to this invention, the resonance circuit is symmetrical in class E push-pull power amplifier circuit using a resonance circuit because a resonance circuit comprising three elements of the first, second and third being connected in series in this order is provided and the first and the third elements on both ends are made to be nearly equal impedance, and if the second element at the center is inductive, the first and third elements at both ends are capacitive, and if the second element at the center is capacitive, the first and third elements at both ends are inductive; and by thus constituting the resonance circuit to be symmetrical, it is able to eliminate the difference of length of copper foil pattern at actual mounting and able to make the high frequency coupling between circuits uniform, as well, which enables operation of two switching elements in ideal condition or a condition close to that relatively easily.

[0023] Further, if a load circuit is connected to the second element at the center, there is an advantage that switching noise is less prone to appear in the load circuit. Furthermore, if a load circuit is connected to the first and the third elements on both ends in parallel, it enables to simplify heat loss design of output transformer for coupling, and there is an effect that adjustment of inductance value of resonance circuit is simplified which is important for realizing high efficiency amplification in class E push-pull power amplifier circuit.

[0024] Further, if the second element at the center among the three elements of said resonance circuit is replaced with two elements of the fourth and fifth elements being connected in series so that impedance is nearly equal to the second element and connection point between the fourth and fifth elements is connected to the ground, it is able to reduce high frequency noise being radiated from the circuit because the center point of the second elements is connected to the ground of the circuit; and it is able to stabilize terminal voltage of each element against high frequency wave too, which has a effect of stabilizing operation of entire circuit.

[0025] Further, there is an advantage that number of parts may be reduced if elements having output capacitance such as field effect transistors are used as the switching elements and their output capacitance is used as entire or a part of the first and second capacitors, respectively, or the load circuit is connected with a transformer and leakage inductance of this transformer is used as the inductive element of the resonance circuit.

[Brief explanation of drawings]

[Figure 1] A circuit schematic showing basic constitution of this invention.

[Figure 2] A circuit schematic showing the first embodiment example of this invention.

[Figure 3] A circuit schematic showing the second embodiment example of this invention.

[Figure 4] A circuit schematic showing the third embodiment example of this invention.

[Figure 5] A circuit schematic showing the fourth embodiment example of this invention.

[Figure 6] A circuit schematic showing the fifth embodiment example of this invention.

[Figure 7] A circuit schematic showing the sixth embodiment example of this invention.

[Figure 8] A circuit schematic showing the seventh embodiment example of this invention.

[Figure 9] A circuit schematic showing the eighth embodiment example of this invention.

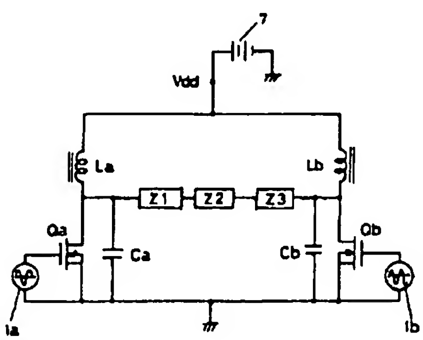
[Figure 10] A circuit schematic showing the

ninth embodiment example of this invention.
[Figure 11] A circuit schematic showing the tenth embodiment example of this invention.
[Figure 12] A circuit schematic showing an example circuit wherein the load is not grounded in the second embodiment example of this invention.
[Figure 13] A circuit schematic of a resonance circuit being shown as a comparable example to this invention.
[Figure 14] A circuit schematic showing the eleventh embodiment example of this invention.
[Figure 15] A circuit schematic of the first previous example.
[Figure 16] A wave shape drawing showing operation of the first previous example.
[Figure 17] A circuit schematic of the second previous example.
[Figure 18] A circuit schematic of a drive signal source being used for the second previous example.
[Figure 19] A wave shape drawing showing operation of the second previous example in the ideal condition.
[Figure 20] A wave shape drawing showing operation of the second previous example off the ideal condition.

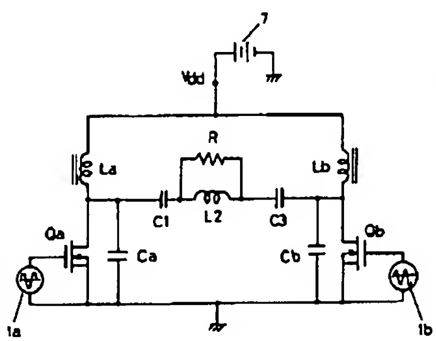
[Description of symbols]

Qa: first switching element
Qb: second switching element
La: first inductor
Lb: second inductor
Ca: first capacitor
Cb: second capacitor
Z1: first element
Z2: second element
Z3: third element

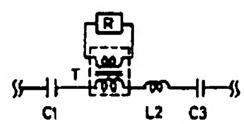
[Figure 1]



[Figure 2]



[Figure 13]



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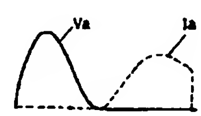
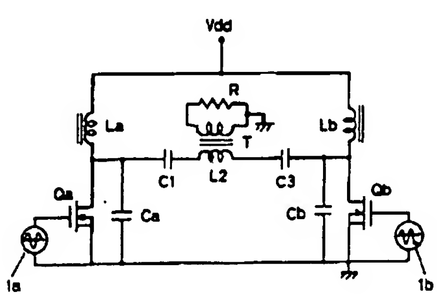
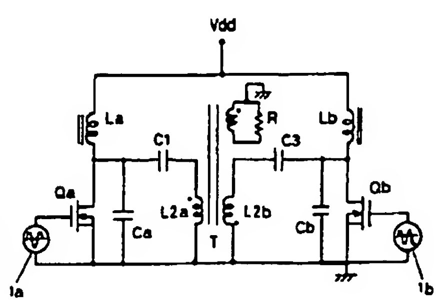


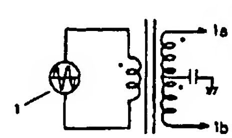
[Figure 3]



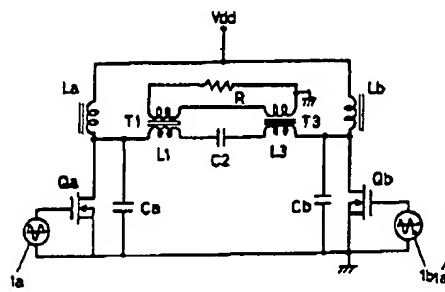
[Figure 4]



[Figure 18]



[Figure 5]



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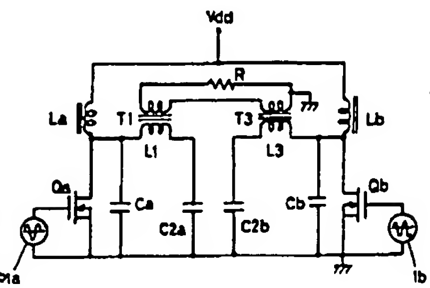

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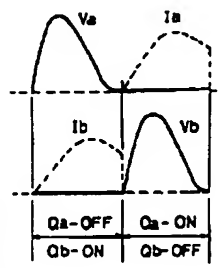

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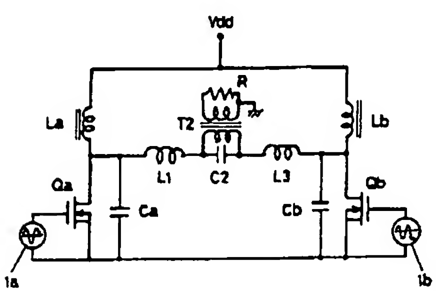

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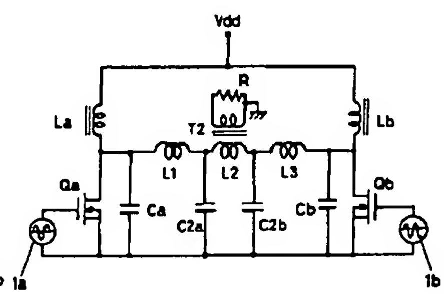

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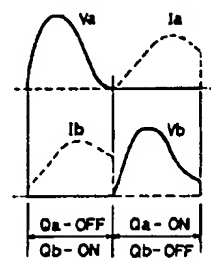

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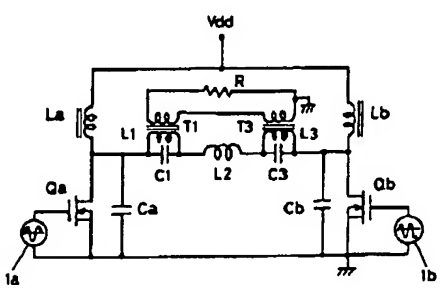

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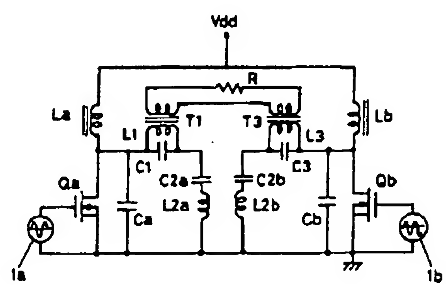

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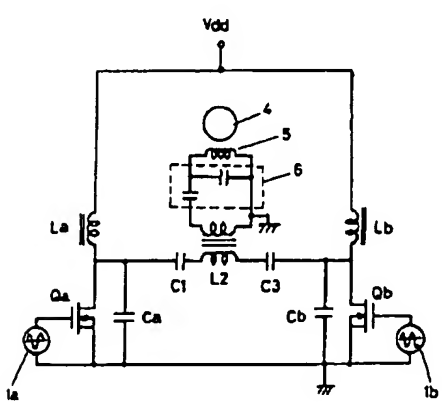

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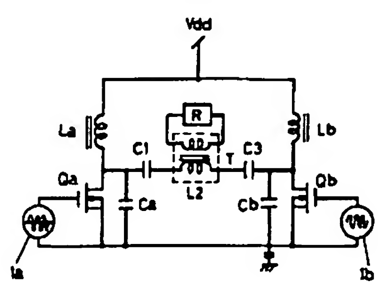

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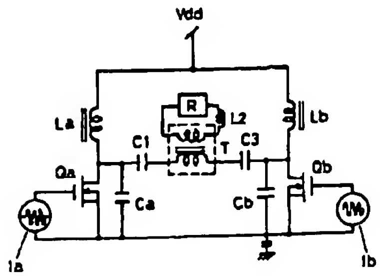

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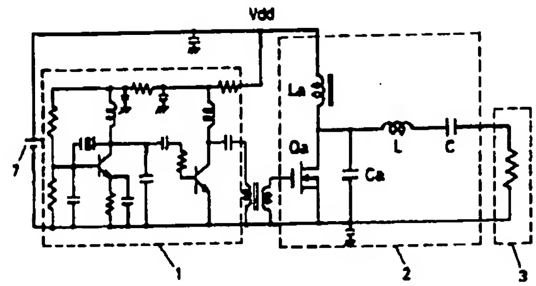

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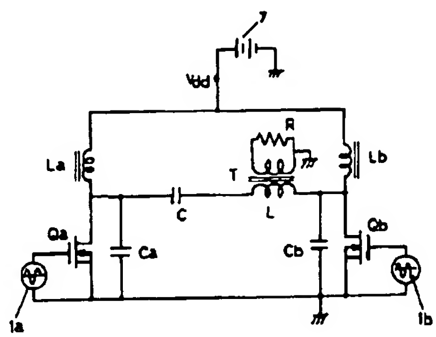

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